

Nanocarbon Thin Films: The Link between Surface Chemistry and Nanotribology

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ABSTRACT

Fundamental understanding of the chemistry and bonding configuration of materials at or near surfaces, particularly at tribological interfaces, is absolutely essential to build reliable MEMS and NEMS devices that involve rolling and/or sliding contacts. Ultrananocrystalline diamond (UNCD) and tetrahedral amorphous carbon (ta-C) thin films have exceptional physical, chemical and tribological properties at the macroscale, nearly equivalent to those of single crystal diamond, and are promising materials for high performance MEMS and NEMS devices^{1,2}. However, little is known about the surface chemistry of these materials, and how it changes with different processing conditions. In our previous studies on UNCD thin films, we have devised methods to control the surface chemistry at the tribological interface through hydrogen termination, which significantly improves its nanotribological properties³. We will review these results and discuss the effect of other chemical termination schemes such as fluorine and hydroxyl groups. We will also report the first comprehensive study of the surface chemistry and nanotribology for as-deposited, furnace-annealed, and laser-annealed ta-C. This is particularly of interest because it is known that as-deposited ta-C possesses high residual stress, and full stress relief is achieved by post-annealing at approximately 650°C. However, no detailed experimental studies have been performed to understand the surface chemistry and bonding configuration of these ta-C films after annealing, which most likely will affect the nanotribological properties as well. We present our approach using a combination of synchrotron-based near-edge X-ray absorption fine structure (NEXAFS) spectroscopy, X-ray photoelectron spectroscopy (XPS), and atomic force microscopy (AFM) techniques to understand surface chemistry, bonding configuration and nanotribological properties of these materials. We show that there are subtle and correlated changes in the surface chemistry, the ratio of sp²- and sp³-bonded carbon, and the local and long-range order on the surface and in the sub-surface region of ta-C. We also show how it changes with different annealing methods used (Figure 1(a) and (b)). The nanoscale friction and adhesion also changes as these materials undergo different processing conditions.

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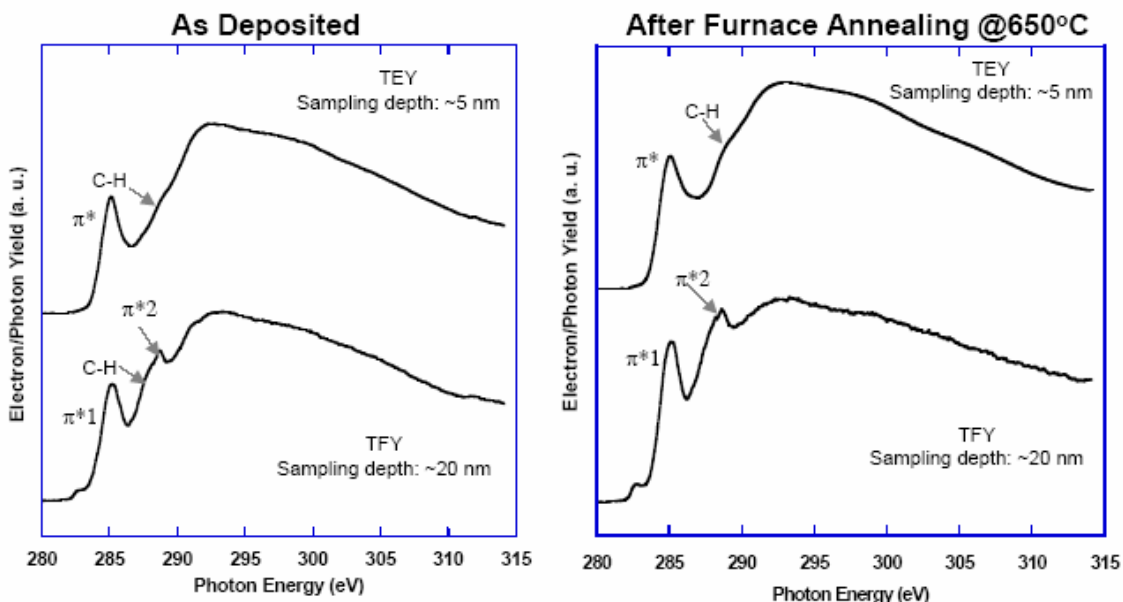


Figure 1: NEXAFS spectra of ta-C at C 1s absorption edge (a) as-deposited and (b) after furnace annealing treatment recorded in electron yield and fluorescence yield mode.

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